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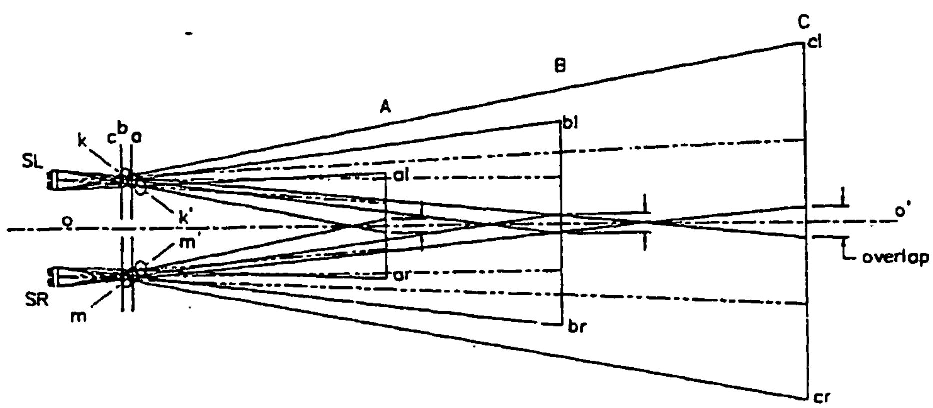

(57) Abstract

The present invention utilizes two-dimensional photosensitive arrays (SR, SL) for decoding two-dimensional optically readable information sets which provides a best focus. A lens is provided for each of the photosensitive arrays movable in a trajectory (k-k', m-m') such that as the lens moves away from the photosensitive array, the distance between the lenses decreases. The varying distance between the lenses provides imnage zones (A, B, C) having the same image overlap in each zone.

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"TWO-DIMENSIONAL, PORTABLE CCD READER"

Technical Field

This invention relates to optical bar code readers, and more particularly to an improved portable device utilizing a photosensitive array for reading two dimensional bar codes.

Background Art

Existing two-dimensional portable bar code readers employ a mechanically scanned laser beam. In one type of such reader, the beam is mechanically scanned horizontally as in conventional, one dimensional bar code scanners, while it is also manually scanned vertically with a downward motion of the hand or wrist. In a more sophisticated type of two-dimensional reader, the laser beam is mechanically scanned in both the horizontal and vertical directions utilizing a raster.

These laser readers require that the scanning beam pattern be accurately aligned with the label symbology, with the degree of accuracy being a function of the vertical height of the coding elements versus the horizontal width. Further, reading the two dimensional codes line by line requires stitching separately read lines or words after they are read. Some two dimensional codes do not provide for stitching. A further limitation of laser scanners for two-dimensional reading is that they require a significant amount of time for the label to be read, which of course requires that the scanner remain accurately aligned with the label throughout the reading process.

Disclosure of the Invention

The present invention utilizes either: (1) a pair of two-dimensional photosensitive arrays (such as charge coupled device arrays), a pair of pointing beams for producing a pair of elongated bright spots on a target, an optical string, control electronics, and a focus indicator; or (2) a single two-dimensional photosensitive array (such as a charge coupled device array), a pair of pointing beams for producing a pair of elongated bright spots on a target, an optical string, control electronics, and a focus

indicator. Both disclosed embodiments utilize the arrays to pick up label images, convert the image to electrical signals, and process the signals with a microprocessor. In the first embodiment each sensor has its own lens system, which provides the proper amount of overlap between the two images produced by the separate optical strings. In both embodiments a distance indicator may be provided to facilitate a user in placing labels to be read at the correct distance from the reader.

Brief Description of the Drawings

FIG. 1 depicts a conventional pair of sensors, each with its own lens, and shows the image overlap provided with the lenses at various positions;

FIG. 2 depicts the sensor and lens system of the invention and its corresponding image overlaps;

FIG. 3 is an enlarged view of the positioning of the left lens of FIG. 2;

FIG. 4 is a block diagram of the present invention;

FIG. 5 is a positioning device of the present invention;

FIG. 6 is an alternative first embodiment of an aiming device;

FIG. 7 is a diagrammatic illustration of the components of a second embodiment wherein a single two-dimensional photosensitive array is utilized; and

FIG. 8 is a graphical representation of beam signal outputs from a reader according to the second embodiment described herein.

Best Mode for Carrying Out the Invention

A. First Exemplary Embodiment

One difficulty with current two-dimensional CCD technology is limited resolution. Commercially available sensors have been developed for television related applications having horizontal resolutions typically limited to 500 to 750 pixels. However, a resolution of from 1000 to 2000 pixels is desirable for providing readability of labels of different sizes and densities.

It is possible to split an image optically and use two sensors with slightly overlapping fields of view. Such an optical system can be based, for example, on a single lens and 50% reflective mirror image splitting optics. This approach, however, suffers from significant losses of optical energy, and also require complicated optomechanical designs for providing the necessary accuracy and stability.

FIG. 1 depicts such a system based on two lenses, one for each sensor. This system, however, produces the desirable amount of overlap between the left and right images only when the target label is positioned at a fixed distance from the sensors. Turning now to FIG. 1, a label positioned in the vicinity designated by *b* would be in

the correct position so that the half images would overlap properly, but the position *a* would produce a missing central area, while the position *c* provides too great an area of overlapping, thereby defeating the purpose of using two sensors.

FIG. 2 also depicts the configuration of an exemplary first embodiment of the present invention. Again, two sensors are used, each with its own lens. These sensors are fixed in a common plane. Automatic focusing is provided by placing the lenses on a carriage that moves toward and away from the sensors. These lenses are mounted on the carriage in such a way that, as the carriage moves away from the sensors, the distance between lenses decreases. As the carriage moves toward the sensors, the distance between the lenses increases. As seen in FIG. 2, the lines *k-k'* and *m-m'* represent the trajectories of the left and right lenses corresponding to the carriage position moving from *c* to *a*. The zones *A*, *B*, and *C* correspondingly show the amount of image overlap between the left and right halves of the total field of view of the system. As may be seen, this overlap is the same for each zone. Therefore, the high total resolution achieved by using two sensors is preserved throughout the entire focusing range of the system.

FIG. 3 illustrates, in greater detail, the position of the left lens during focusing. The individual lens viewing angle must be larger than would be required for ordinary imaging of the same field since the axis of the sensor's sight (originating in the center of the sensor) skews away from the optical axis of the lens when the carriage is in other than the midpoint position.

The block diagram of FIG. 4 depicts the major components of the two-dimensional CCD reader. Before a two-dimensional CCD device may be utilized as an image sensor for reading two-dimensional optical information sets two problems must be overcome, first, the difficulty inherent in processing the data produced by a two-dimensional array, and second, the difficulty inherent in minimizing memory space requirements when working with the array's data output.

The present invention solves these problems in part via utilization of the CCD sensor storage capability. Both vertical and horizontal CCD shift registers are, in essence, analog storage devices used as an intermediate Read Once Memory (ROM), situated between the array of the photo receptors (photodiodes) and the image processing hardware. The system architecture, represented in FIG. 4 allows the microcontroller **8** (referred to as a DSP) to have direct control over the sensor 1 scanning processes via HVC pulse control circuit 7. This HVC circuit generates the clock pulses necessary for moving electrical charges from the photodiodes to the

vertical shift registers, for moving charges in the vertical registers, for shifting them inside the horizontal shift register and for controlling the correlated double sampling device 2. The vertical driver 4 serves as a power stage for the vertical clock pulses. The microprocessor 8 originates the control signals to the HVC chip 7. These signals cause the CCD to perform an image charge transfer, a line by line vertical shift and a pixel by pixel horizontal shift.

The analog signal appearing on the output of the CDS chip 2 is available to the inputs of the A/D converter 3 and the comparator 5. The other input of the comparator is connected with the output of the D/A device 6. The D/A is equipped with an internal input latch. This architecture provides:

(1) line shifting separately from pixel scanning;

(2) shifting pixels along the horizontal register either by processing the pixel data or dumping it;

(3) input the pixel illuminance values to the DSP as gray scale values produced by the high resolution A/D converter 3;

(4) input the pixel illuminance values as black/white single bit values produced by the data reduction comparator 5.

So that a decodable image may be obtained, some image corrective actions are also provided, e.g., exposure adjustment, focusing adjustment (long range readers). An exemplary solution is to take a *service image* or *service frame*, measure certain parameters of the image such as image quality (contrast, brightness, sharpness, and the like) adjust the sensor control parameters and take a second improved image frame.

Since information about image quality is redundant, it is not necessary to study the entire image. This is where the direct control of the vertical shift becomes useful. Since the luminosity distribution along the image area may not be uniform, it may be necessary to study the whole image frame area, but with the limited sampling frequency. Since the non-uniformity of the distribution of the signal bright and dark levels is a smooth function of x and y sensor coordinates, samplings of this function may be taken infrequently, for example as a matrix of 10 samples evenly spread along horizontal lines by 10 samples vertically, i.e., 100 samples. Based on these samples, the corrections for the next frame may be accomplished.

When the service frame is of acceptable quality, the before mentioned samples are used to calculate the threshold function for the next frame image data compression. The threshold function is a 3-D surface that is stretched in the

coordinate of *x* and *y* sensor pixels and having vertical coordinate as the image brightness or illuminance. If properly calculated, this surface must intersect the image 3-D function on the middle level between the dark and bright levels of a bar code two dimensional image. Having only about 100 points, representing the threshold surface, small memory storage is required. When the "info-frame" is taken for image processing, the DSP outputs the threshold points to the D/A converter at the appropriate moments during the frame scanning. These points are locked in the D/A's latch until they are updated with the following values by the DSP. The comparator 5 compares each pixel value with the threshold surface and produces a high contrast black/white image. This compressed image data is read by the DSP either through polling or the interrupt, which occurs at each transition from black to white and from white to black.

The "info-frame' processing is combined with image acquisition. Since the regions of the label image carry enough information for decoding data residing in those regions, it is not necessary to have a complete image from a pre-stored memory prior to starting the decoding process. To save memory, only a limited number of lines are acquired, binarized and stored in the DSP RAM. Practically, about 40 lines may be stored in the processing image buffer. After a current strip of an image has been decoded, the strip of the next 40 lines is acquired from the sensor and is placed in the same buffer abutted to the preceding strip. Only a few lines from the preceding strip is required, to assure continuity. The number of this overlap depends on the structure of the label code and the desired skew angle tolerance. Thus, the processing image buffer is a circular buffer, with some 40 plus lines of the binarized image. A minimum memory capacity for this kind of buffer is: 50 lines x 750 pixels per line = 37500 bits or 2344 words.

Thus, the aforementioned description denotes how economizing of both processing time and computing facilities is accomplished.

FIG. 5 depicts a reader positioning apparatus. *S1* and *S2* each produce illuminating beams, which converge at a position from the reader where a two-dimensional bar code is focused. In this embodiment the illuminating spot is rectangular, and outlines the viewing area.

An alternative first embodiment of a reader aiming device is depicted in FIG. 6. In this embodiment, *S1* and *S2* produce narrow beams of light which converge to indicate the center of the viewing area and the optimum focus distance.

B. Second Exemplary Embodiment

FIGS. 7 and 8 depict a second exemplary embodiment for a two-dimensional portable optically readable information reader. Turning first to FIG. 7 wherein it may be seen that two pointing beams are provided (*S1* and *S2*) for producing elongated bright spots (***a*** and ***b***) on a target surface ***Q***. When this surface lies in a plan at a readable distance from the reader, both spots (***a*** and ***b***) merge. Conversely, where the target surface lies in a plan which is not at a readable distance from the reader, the spots (***a*** and ***b***) are separated by a distance ***m***, which is a function of the displacement of the target surface and the best focus position.

The beams may have a wavelength selected from the visible portion of the electromagnetic spectrum (such as those produce from read or green LED's), or infrared sources may be utilized. In either case the elongated profile of the beams facilitates capturing of the spots by the array during the taking of a ***service frame*** (FIG. 8), which is processed much faster than an ordinary ***data frame***. This reduction in processing time is accomplished by simply skipping most of the horizontal lines in the frame and studying only about three percent (3%) of the regularly spaced lines. Elongated or fan shaped spots (***a*** and ***b***) are preferred since round or narrow spots may be missed if the spot's image fell between the active horizontal lines of a service frame.

The distance ***m*** is then measured by the reader's computer and is displayed on the indicator (e.g., as a line of variable length, or as a variable sound pitch) such that an operator may quickly adjust the distance between the reader and the target even where the label to be read and the spots (***S1*** and ***S2***) are not visible.

If the distance ***m*** between the spot images is defined as:

$$m = b - a$$

and ***a*** and ***b*** are horizontal coordinates of the spots in the service frame, it becomes negative when $a > b$, this is true when the target surface ***Q*** is out of range. So the sign of the ***m*** distance is an indicator of whether the surface ***Q*** is too close or too far from the best focus distance. For positive identification of the spots (***a*** and ***b***) the computer may tum the beams (***S1*** and ***S2***) on and off or otherwise control the amount of energy in each separately in sequential service frames.

As noted before, the "service frame" provides all necessary information for adjustments, so an image of acceptable quality can be made, such that the "info frame" may be processed successfully and quickly.

This may be accomplished according to the following: (1) the selected sensor for this application has a matrix of 752 x 582 useful pixels; (2) there are two fields: odd and even; (3) each field consists of 291 interlaced horizontal lines; (4) each line has 752 pixels; (5) any one field contains sufficient data for a "service frame", therefore after processing one "service field" a decision may be made regarding adjustments before another "service field" or an "info frame" is taken.

During acquisition of a "service field" only 12 equally spaced horizontal lines are processed (one in each of 24 lines). The other 23 lines of each 24 are skipped (not acquired). Skipping or dumping of the lines may be done with a much higher rate (20 Mhz in the present embodiment). The 12 active lines are processed in the following manner: (1) each line is divided in 16 sections of 47 pixels each; (2) one half of each section (24 pixels) is taken for processing, while another half (23 pixels) is skipped; (3) out of the 24 pixel values two extreme values, brightest and darkest, are found and their differences are stored in a "modulation array". The modulation array is organized as a 0fH x 0bH (16 x 12 decimal) matrix. A mean value for each of the 24 pixel strips is also calculated and stored in the "threshold array", organized similarly to a "modulation array". The examples of both arrays are shown in the following tables:

TABLE 1.
Raw Threshold

	0	1	2	3	4	5	6	7	8	9	a	b	c	d	e	f
0	00ad	00c0	00d0	00da	00db	00e2	00e0	00ec	00e9	00f1	00fb	00fd	00f0	00e5	00e4	00d9
1	00b2	00c5	00d9	00db	00e6	00ea	00f8	00fa	00fc	010b	0110	0112	00f8	00fa	00f1	00e3
2	00b3	00c8	00d2	00e2	00ec	00fa	00c3	00cb	00c3	00bc	00c6	011a	0119	0104	0101	00f5
3	00af	00bf	00da	00e3	00fb	0110	00ad	00b1	00a8	00ab	00ec	0123	0121	0123	0121	0108
4	00bd	00d2	00d9	00f1	00fc	010b	0095	00ba	00ab	00b4	00bb	0126	0128	0122	0120	011a
5	00c3	00d5	00e2	00f4	00fb	0111	00c2	00b8	00be	00bd	00c2	012b	0121	0121	0120	010c
6	0060	00c3	00e0	00ea	0100	0103	0118	0121	0123	0126	0129	0128	0122	011b	0119	0102
7	00ae	00bd	00db	00e9	00fe	0103	011b	0120	0128	0132	0132	0132	0123	011b	0119	0102
8	00b1	00cd	00e0	00e4	00fc	010d	0120	0122	011b	0123	012c	0129	0121	011a	0111	00f4
9	006d	0089	0099	00a3	00b9	00c9	0110	011a	0121	0121	0122	0121	0112	0113	0100	00f5
	00bf	00cd	00e0	00eb	00f2	0104	0118	011b	0118	011a	011b	0119	0101	0105	00f1	00f0
	00be	00d3	00e1	00f1	00f4	00fd	0104	0119	0118	011b	011b	011b	0105	0103	00f3	00e2

TABLE 2.
Raw Modulation

		370	3ad	3ba	392	40b	504	61f	66f	641	519	40e	30d	327	336	
0	0011	0018	0018	0012	0013	001a	0018	001e	001f	0017	0023	001f	0018	0017	001a	0011
1	0014	0017	0011	0013	0018	0012	0010	0010	0010	0003	0008	000a	0010	0012	0019	000b
2	0013	0010	000a	0018	000e	0010	0045	0051	0055	004e	0048	0012	0011	0016	0017	0019
3	0017	001f	0012	0015	0013	0008	0061	0067	0060	0063	0042	0019	0019	001b	0019	0020
4	001b	000a	000f	0017	0012	0003	0049	0072	005d	0068	005d	001f	0020	001a	0018	0012
5	0015	0015	001a	001a	0013	0009	0048	0058	0060	0061	0068	0013	0017	0019	0018	001e
6	0012	0017	0018	001e	0018	001b	0010	0019	0019	0013	0011	0010	0016	0013	0011	001a
7	0014	001b	0013	0021	0020	001b	0013	0018	0020	001a	001a	001a	0019	0013	0011	001a
8	0011	0011	0018	0016	001e	001f	0018	001a	0013	0019	001e	0011	0019	0012	0017	0018
9	002d	003f	0051	004b	0041	003f	0008	0012	0019	0019	001a	0019	000a	000b	0018	0019
a	0011	0013	0018	0013	0016	0016	0010	0013	0010	0012	0013	0011	0019	0017	0019	0018
b	001e	0019	0019	0019	001a	0011	0016	0011	0010	0013	0013	0013	0019	001b	001b	001a
	0	1	2	3	4	5	6	7	8	9	a	b	c	d	e	f

The modulation array reflects areas of data activity in the image frame. The rectangular area with the *xy* coordinates (column * raw) of: 62, 65, a2, a5 has elevated modulation values and indicates the image of the label (in this particular example a UPS-code label was used.). The next procedure pinpoints the middle of the area of interest. For this purpose a low pass spatial filter is applied to the array of modulations as a running window of 3 units wide, independently of horizontal and vertical coordinates. The result of this processing is the two linear arrays (14 and 10 values long correspondingly). Maximum values (and the label middle) is indicated in bold typeface.

The next object is to identify the boundaries of the label area. For this purpose a tolerance value is calculated as a function of an average modulation in the middle of the label (Mm) and average modulation for a large vicinity, surrounding the label (Mv).

Mm - 1/9 m9

Modulations of 9 elements of a 3 x 3 matrix with the determined label center in the matrix are added together and divided by 9.

Mv - 1/81 m81

A similar operation is performed on 81 elements of a 9 x 9 matrix. Thus, a tolerance value Tm = (k * Mm + Mv)/2k. For this example k = 4 is an optimum because the vicinity area (81 points) is 4 times greater than the label area (4 x 5 = 20 points). Next, the modulation values are being compared with the tolerance value, starting from the determined label center, and moving outward until lesser than Tm values are found. One more row or column is then added to this area for safety. The *x* and *y* coordinates, outlining the zone of the label are stored. These coordinates are used for optimum processing of the info-frame. All lines preceding (and following) the outlined zone in the frame may be disregarded. The information positioned to the left and to the right of the outlined zone may also be disregarded and need not be acquired. This process of line skipping and pixel skipping substantially reduces the image processing time.

Threshold surface values may be found by simply averaging 9 threshold values for a 3 x 3 matrix surrounding the determined label center and applying this averaged threshold for the whole zone. This method is acceptable for relatively small size labels (like UPS-code labels), for which variations of illumination intensity do not vary significantly within the label area. For large size labels, (like some PDF 0417 code labels) adaptation of the threshold surface within the label boundaries is required. In

this case, in the array of "raw" thresholds, each number situated externally to the label and immediately next to a threshold value on the border of the label (more accurately, a blob representing a presumed label), is substituted with the value of the nearest blob value for the purpose of calculations. Then the low pass 3 x 3 filter is applied to the area inside the blob boundaries. The resultant array of smoothened threshold values then may be used as the thresholding surface for the fast preprocessing of the info-frame. As discussed earlier, these values are loaded by the DSP in to the comparator during the info-frame acquisitions.

C. Exposure Control

In order to properly function in a variety of lighting conditions the present invention is preferably provided with exposure control means. Ambient light conditions may commonly range from 3 to 100,000 lux. An office illuminated by fluorescent lamps typically ranges from 300 to 500 lux. Fluorescent lights normally flicker at a frequency of twice the alternating power source frequency.

Therefore, a preferred embodiment of the present invention should work in flickering lighting conditions and be adjustable from 30,000 to 1. The ratio between the maximum and minimum instant values of illumination intensities are normally on the order of 3 to 1 (where 90° phase shift lighting is not utilized). It is also necessary, in a preferred exemplary embodiment that sensor sensitivity adjustments take place in a matter of millisecond such that the amount of time remaining for image acquisition and decoding is optimized.

As disclosed herein, the present invention describes a method and apparatus for reading two-dimensional optical information sets, which delivers image information sequentially in "frames" which are divided in two fields where a interlaced type television sensor is utilized. Where a non-interlaced sensor is utilized each "frame" constitutes a single field. According to the present invention these fields may be classified into two groups, i.e., "service-field" and "information field."

Service fields are processed much more rapidly than are information fields. Service fields are processed only for camera house-keeping purposes, i.e., sensitivity adjustments and the like. In an exemplary preferred embodiment sensitivity adjustments may be made according to the following method:

(a) A first field is taken with a default exposure of 417 μs where a non-interlaced sensor is utilized. Where an interlaced sensor is utilized the first field is exposed for 417 μs and the second field is exposed for 50 μs.

(b) The first field is analyzed to determine the ambient light level (illumination level). Where the level of illumination of the first field is insufficient the exposure time is increased, in such a case two conditions are possible:

(1) The signal level is determined to be reliable for calculating an optimal exposure time (in such a case the exposure time is modified accordingly and an information-field is acquired). The maximum exposure time is 4.17 ms (based upon empirical studies of image smear caused by hand motion and the like), and the tolerable exposure time is between 4 to 5 ms (by selecting 4.17 ms certain advantages are obtained). If the required optimum exposure is between 4.17 ms and 12 ms (dim level), the information-field is taken with 4.17 ms exposure and the ADC reference levels are adjusted to preserve contrast ("image normalization"). If exposure time is calculated to be more than 12 ms (dim level), then auxiliary lighting is utilized (xenon strobe light or the like) during acquisition of the information-field.

(2) The signal level is found to be too small to calculate optimum exposure. In this case the auxiliary light source is also used (assuming very dark ambient lighting conditions).

(c) If the first service field, taken with the default exposure produced an image which is too bright, a second service-field is taken with the exposure reduced by a factor of ten (47 ms). With this exposure setting an accurate prediction of optimal exposure may be made. However, if the image is still to bright a third (or subsequent) service-field may be taken. When an unsaturated white level is determined optimum exposure time is calculated and the information-field is acquired.

Claims

1. A two-dimensional, portable optical information reader, comprising:

(a) a housing having a window;

(b) at least one photosensitive array mounted within said housing and behind said window, said array for converting images into corresponding electrical signals;

(c) an optical string between said housing window and said array for focusing images of optically readable information on said array;

(d) at least two electromagnetic beam generators mounted on said housing such that the beams of said generators cross at the point of best focus of said optical string;

(e) computer means for processing said electrical signals from said array; and

(f) an indicator for indicating to an operator the position of best focus of said reader.

2. A two-dimensional, portable CCD reader, comprising:

(a) a first two-dimensional CCD sensor array and a second two-dimensional CCD sensor array, said first CCD sensor array and said second CCD sensor array fixed in a common plane;

(b) a first optical lens and a second optical lens, said first optical lens moveable relative to the optical axis of said first sensor array, and said second optical lens moveable relative to the optical axis of said second sensor array;

(c) means for reciprocating said first and said second optical lenses relative to their respective sensor arrays; and

(d) means for accurately positioning the CCD reader relative to a bar code to be read.

3. The reader of claims 1 and 2 further comprising exposure control means for adjusting the sensitivity of said sensor to varying ambient light conditions.

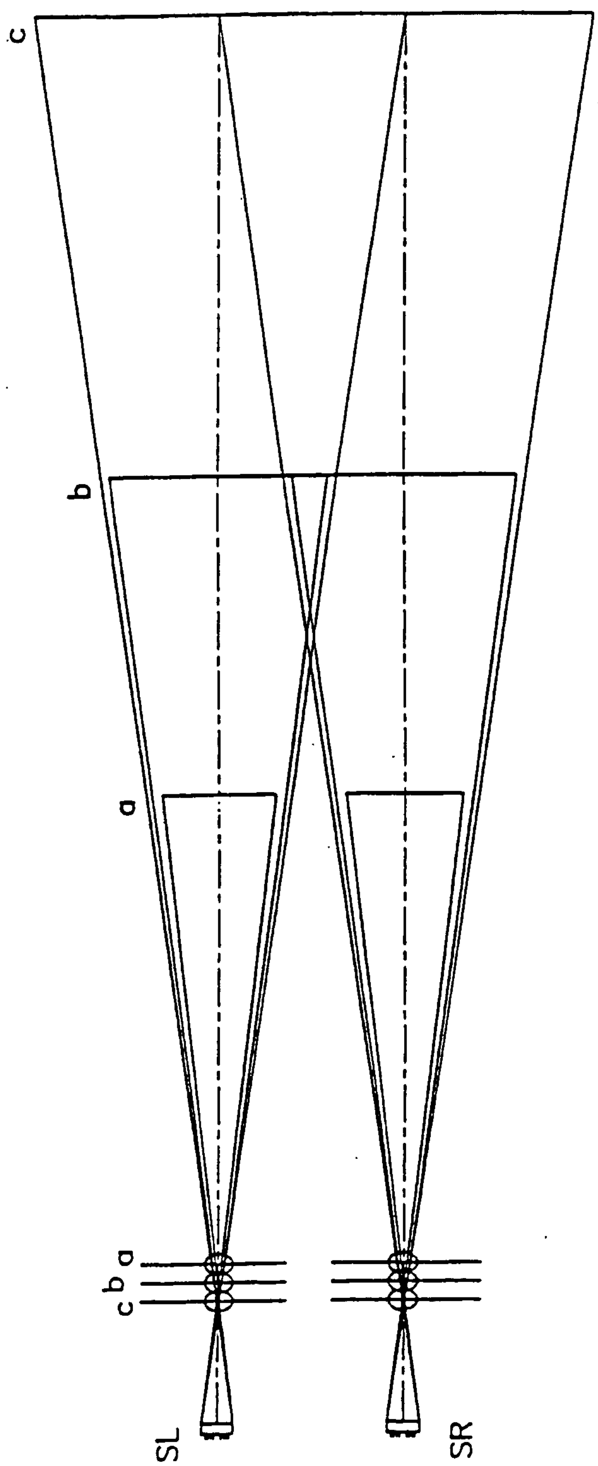

FIG. 1

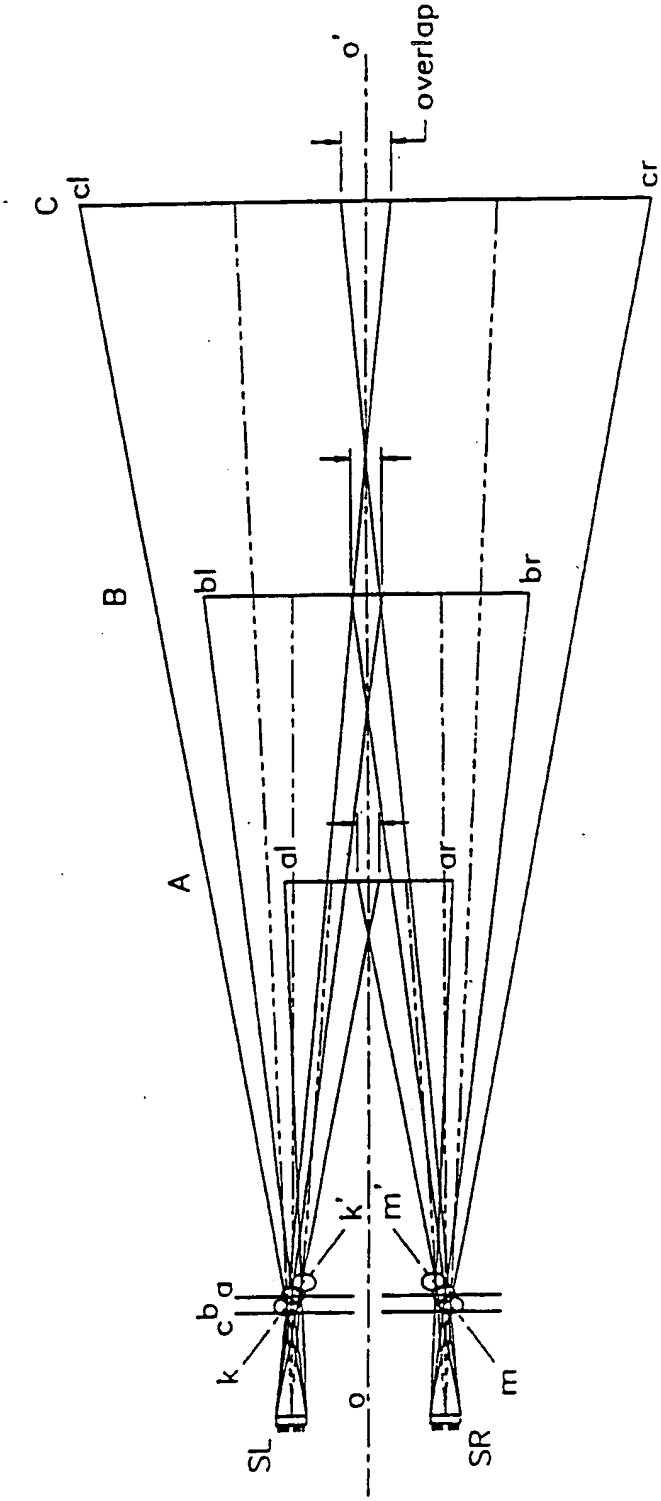

FIG. 2

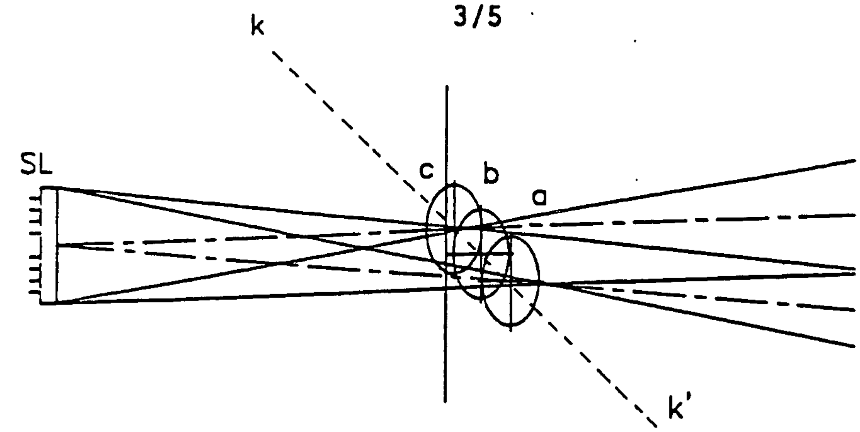
k
SL
c
b
a
k'

FIG. 3

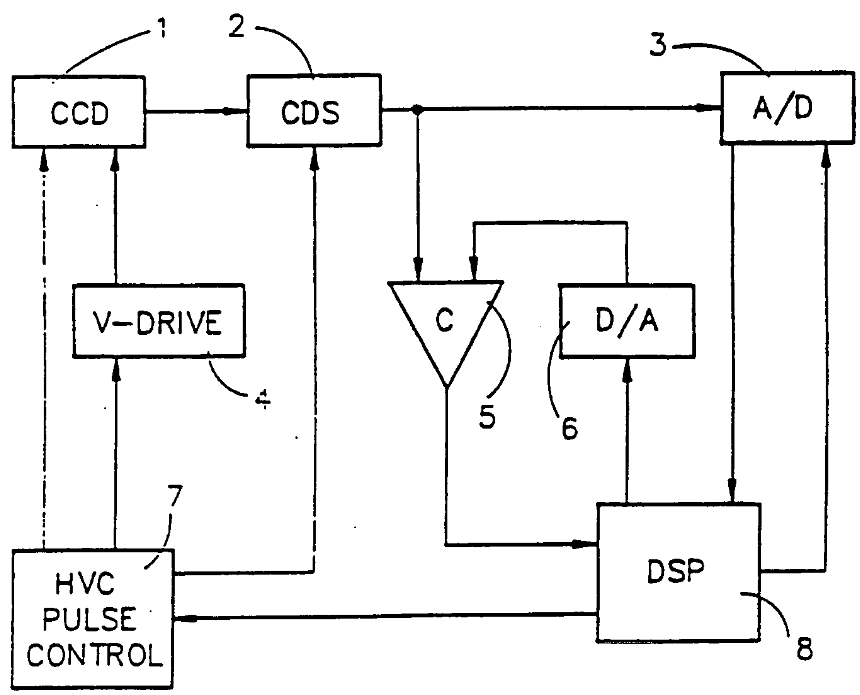
1
2
3
CCD
CDS
A/D
V-DRIVE
C
D/A
4
5
6
7
HVC
PULSE
CONTROL
DSP
8

FIG. 4

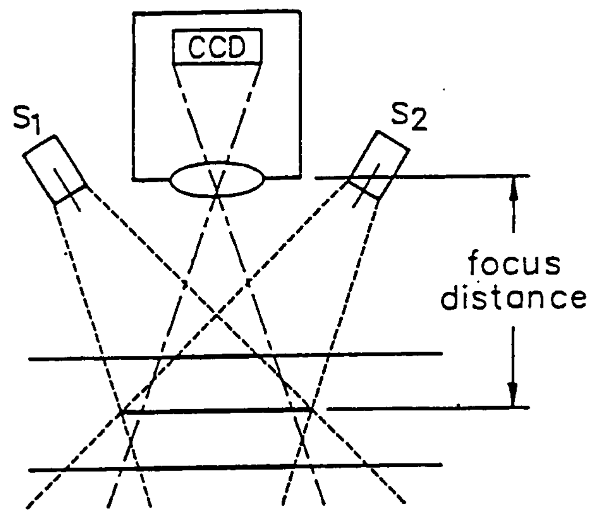

FIG. 5

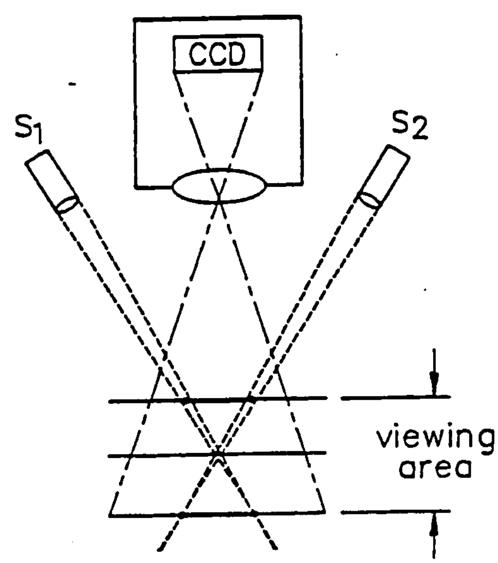

FIG. 6

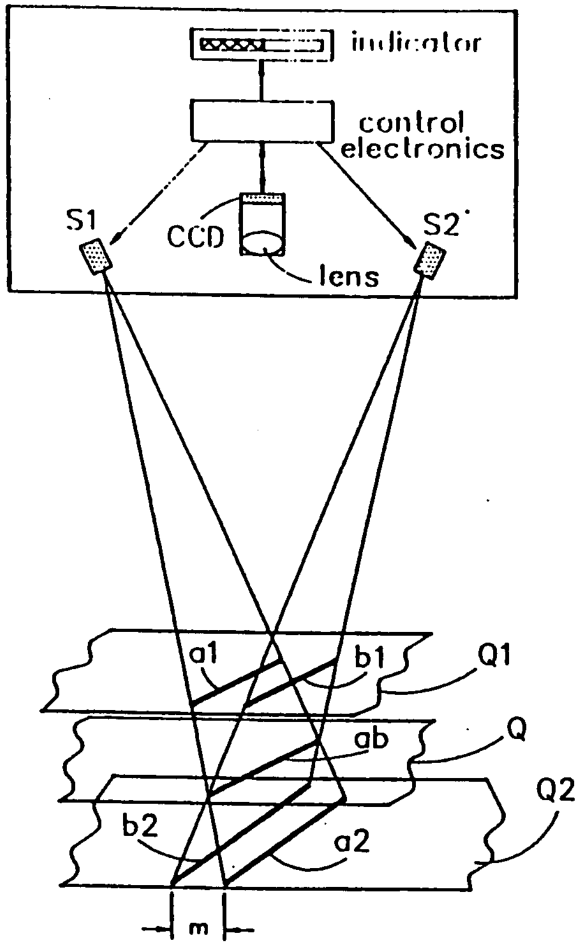
indicator
control electronics
S1
CCD
S2'
lens
a1
b1
Q1
ab
Q
Q2
b2
a2
m

FIG. 7

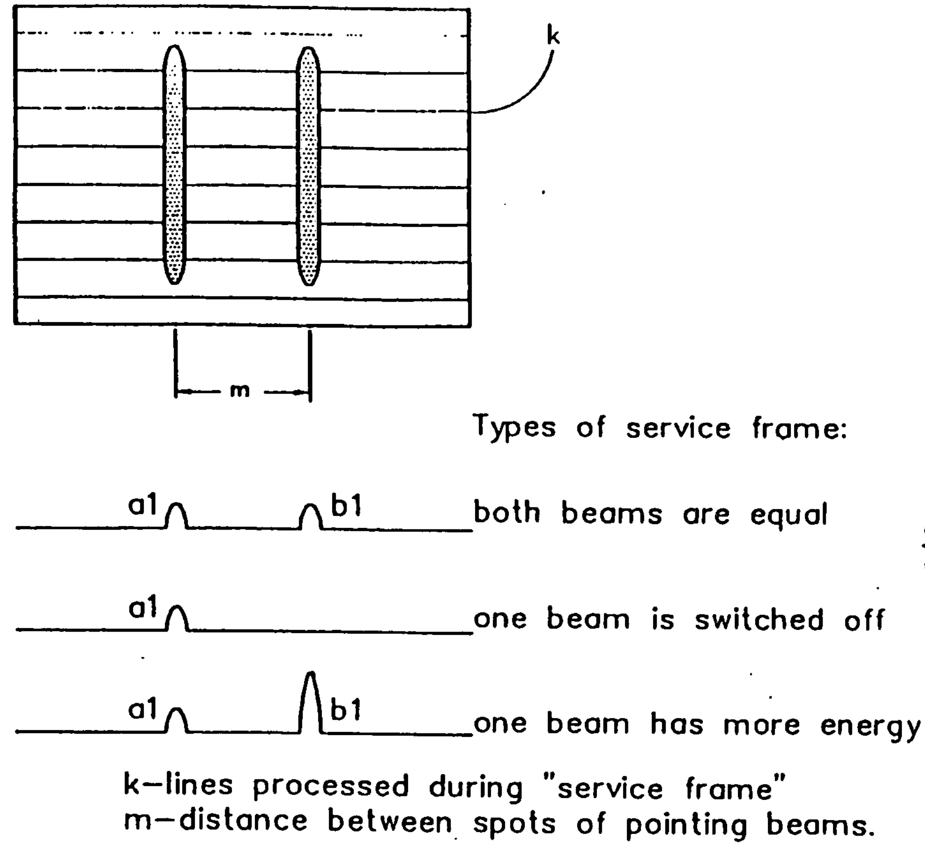
k
m
Types of service frame:
a1
b1
both beams are equal
a1
one beam is switched off
a1
b1
one beam has more energy
k–lines processed during "service frame"
m–distance between spots of pointing beams.

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/05380

A. CLASSIFICATION OF SUBJECT MATTER
IPC(5) :G06K 7/10
US CL :235/462; 348/218
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 235/462, 472; 348/218

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS: search terms: movable, lens, image overlap, exposure control

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,389,103 (KRAMER) 21 JUNE 1983, col. 8, line 54 to col. 9, line 19, and Fig. 7.	2
Y	JP, 63-67692 (TAKADA) 26 MARCH 1988, Fig. 4.	1
Y	US, A, 4,335,302 (ROBILLARD) 15 JUNE 1982, col. 8, line 63 to col. 9, line 35.	3
A	US, A, 5,159,455 (COX ET AL) 27 OCTOBER 1992	2
A	US, A, 4,323,925 (ABELL ET AL) 6 APRIL 1982	2
A	US, A, 4,660,096 (ARLAN ET AL) 21 APRIL 1987	2

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 01 SEPTEMBER 1994	Date of mailing of the international search report 12 SEP 1994
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